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IMPERIAL BUREAU OF MYCOLOGY

PEACH CANKER

BY
W. A. McCUBBIN, M. A.
ASSISTANT IN CHARGE OF FRUIT DISEASES
DOMINION PLANT PATHOLOGICAL LABORATORY
ST. CATHARINES, ONT.

BULLETIN No. 37
Second Series

Published by direction of Hon. T. A. Crerar, Minister of Agriculture, Ottawa, Ont.

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J. DE LABROQUERIE TACHÉ
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OTTAWA, May 1, 1918.

The Honourable
THE MINISTER OF AGRICULTURE,
Ottawa.

SIR,—I have the honour to transmit herewith the manuscript of Bulletin 37, of the second series, entitled "Peach Canker" and prepared by Mr. W. A. McCubbin, Assistant in Charge of the Plant Pathological Laboratory at St. Catharines, Ont. This bulletin is the result of some six years' investigation by Mr. McCubbin in the control of this disease. His studies in this direction have led to very satisfactory results, and there now exists no reason why the disease should continue to prove injurious in peach orchards. The bulletin as now prepared is of a technical nature and hardly suited to general distribution, so that I would recommend that only a small edition be issued. Should a demand for it arise a popular edition may be prepared later.

I have the honour to be, sir,

Your obedient servant,

J. GRISDALE,
Director, Dominion Experimental Farms.

PEACH CANKER

BY W. A. McCUBBIN

In passing through the peach orchards of Niagara peninsula, or elsewhere in Ontario where peaches are grown, one constantly meets with large, dark, gummy lesions on the trunks or limbs of the trees (pl. I, fig. 1; pl. II, fig. 7). This diseased condition of the branches was formerly given the name of "gummosis" on account of the gum exudations which are so regularly associated with it, but a closer study of its nature indicates that this disease clearly belongs to the type of affection known as canker, for which reason the latter name is now adopted.

Peach canker in Ontario was first mentioned in a bulletin by Caesar, in 1911,[1] wherein he notes that, judging by the condition of the older orchards, and according to the evidence of experienced growers, the disease was then of recent introduction, having first appeared in any noticeable amount about 1908. In the Central Experimental Farms report of 1911 the Dominion Botanist called attention to the prevalence of the disease in the Niagara peninsula, and ventured the opinion that it seemed to be due to a specific cause. In 1912 a paper by Jehle, of Cornell,[2] appeared, in which the cause of this affection was ascribed to the Brown Rot fungus, while Rolfs in Missouri had already shown[3] that cankers, killing of twigs, and gum formation, followed the attacks of the fungus *Valsa leucostoma*, a common deadwood fungus on the peach.

Earlier writers, both in Europe and America, had noticed the extraordinary outpouring of gum that frequently takes place in stone fruits, and giving it the name of gummosis, the cause was variously assigned to the action of frost, fungi, or to some physiological condition.

In view of the widely divergent opinions that were extant concerning this disease when the writer took up the work of plant pathology in the Niagara District in 1912, it was thought desirable to undertake some investigations into the nature of the trouble as it was there found, and to see if some means might not be found to prevent or lessen it. This work has been carried on with many interruptions since that time, and the results are now placed before the peach growers of the province in the hope that they may be of material aid in dealing with what seems to be an increasingly injurious peach disease.

DESCRIPTION OF CANKERS.

The most conspicuous feature about the canker disease is the gum which almost invariably accompanies it. When first poured out this gum is of a light amber colour or even almost colourless, but in the course of the season it becomes brown and is overgrown by a black, crust-like fungus layer. The blobs of gum also dry out and harden, so that an old canker in dry weather greatly resembles a large, rough Black Knot (pl. I, fig. 1; pl. II, fig. 7). In rainy weather this gum may be easily removed with a knife, and the nature of the canker may be made out. If the canker is an old one the original bark covering it will have been broken up and disorganized; but in a younger specimen the old bark layer may still be in place. Under this band-like outer bark the inner bark is seen to be browned and dead, and much mixed up with gum. After clearing out this mass of gum, bark, and dead tissue, one can make out the exact extent of the canker. It is then

[1] Peach Growing and Peach Diseases–Ontario Dept. of Agr. Bulletin 201, p. 38.
[2] Phytopathology, Vol. 3, No. 2, p. 105, April 1913.
[3] Winter killing of twigs, Cankers, and Sunscald of peach trees; Missouri State Fruit Experiment Station Bulletin 17, May 1910.

seen to be an open wound in the bark, usually with a stub, twig, or dead limb in the centre (pl. 2, fig. 8; pl. 6, fig. 27). It is longer up and down the limb than across, and all around the edge is a cushion-like growth of healthy tissue where the living part of the limb borders the wound. Often the callus ring is conspicuously large, and this swollen condition extends for some distance back from the central open area (pl. 3, fig. 14). It is apparent that something connected with the canker has strongly stimulated the surrounding living tissue so that it grows much more vigorously than the ordinary tissue of the limb, and thus forms a swollen callus ring. In weak or unhealthy limbs this excessive growth is lacking and there is only a thin, weak callus formed about the wound, barely enough in some cases to make a visible ridge under the bark (pl. 2, figs. 9–10).

In old cankers there are to be seen one or more dead, ring-like growths of the same sort between this callus at the edge of the live bark and the centre of the canker, and one readily understands that the canker has enlarged because of the death of former callus growths for some distance back each year, after which a new callus growth appeared farther out (pl. 1, fig. 5). As each of these callus rings died, gum was produced which was pushed out thorugh the bark in large masses. These gum masses obscure the real nature of a canker, but by clearing them away it becomes plain that in its essential features a canker is an open wound starting from a small centre and slowly enlarging by the yearly death of the callus tissue at the edges.

DAMAGE CAUSED BY CANKERS.

Although in a few cases cankers have been found which have healed up of themselves, temporarily at least, this healing does not often take place under natural conditions. Usually there is a gradual yearly extension of the dead area until the limb is either girdled or else so weakened that it breaks off in the stress of a storm or with the weight of a fruit crop (pl. 1, fig. 6).

In 1916 an orchard survey was made to ascertain just how much damage was due to cankers in this way. It was found that out of 3,766 trees covered by this survey in twelve orchards, 255 trees or almost 7 per cent of the trees were suffering from breakages, and of these 255 broken limbs, 233 or 91·4 per cent, had broken at a canker. It is certain, therefore, that there is a considerable annual loss which is thus directly due to cankers. An attempt was made in this survey to determine the amount of this loss as nearly as possible. The fraction of the tree lost by each broken limb was estimated, and when all the 255 fractions were added they totalled about 85 whole trees. In other words out of 3,766 trees 85 trees, or 2·25 per cent, were lost in one year by breakages largely due to cankers.

Now an acre of peach trees set 18 by 18 feet contains 134 trees, and according to our findings the annual loss from cankers in this number of trees amounts to slightly over three trees. Bearing trees have been variously valued by practical growers at from $5 to $10 each. Accepting the lowest estimate of $5 per tree it is apparent that there is an annual loss per acre of $15, or $150 a year for a ten-acre block.

It must be remembered, too, that this estimate covers only the losses due to breakage. Many other limbs are girdled and die without breaking, or grow sickly and are pruned off, because of cankers. In addition, cankers on the trunk and in crotches may keep the tree sickly and unproductive for years without causing any actual loss by breakage. In the survey table on page 8 there are recorded on 110 trees, 37 trunk cankers and 88 crotch cankers. At a conservative estimate the total loss from cankers probably runs from 2 to 4 per cent annually, or about $10 to $20 per acre.

This breakage loss is much increased each year because of the action of heart rot fungi which invade the open wound and weaken the heart-wood of the branch. The sound heart-wood of the peach, as everyone knows, is of a clear

light or amber colour, and is firm and hard. When these fungi have lived in it for a few months it becomes soft and brittle and takes on a pale or ashy white colour. Examination of a few broken-down limbs in the fall will convince any fruit-grower of the reality of the damage done by these rot fungi, and it need only be added that in the 255 cases of limb breakage found in the survey just mentioned, 150 or 58·8 per cent, were suffering from heart rot which had weakened these limbs and hastened their fall.

DISTRIBUTION OF CANKERS.

The disease is rather uniformly distributed all through the Niagara peninsula, and occurs to a greater or less extent in the peach districts of Lambton, Essex, and Kent. In fact it is to be found wherever peaches are grown, though the newer peach districts are as yet not so badly affected as the old, well-established areas.

There is a considerable local variation in its occurrence. Those districts where the soil is hilly, and where there is deep sand with good soil drainage, are less affected than the low-lying, level lands where both air and soil drainage are poor. Even in the same orchard a well-drained knoll may be much less subject to canker than the low, moister parts. The disease is noticeably worse also in orchards situated in hollows, or closely sheltered by woods.

In many cases there is such a marked difference in adjacent orchards in the amount of canker present that one cannot help concluding that improper orchard practice has a great deal to do with the encouragement of the disease.

THR NATURE OF CANKERS.

Gum in Cankers.—On account of the usual tendency to associate cankers with extensive gum production, a few words of explanation may be given here relating to the general occurrence of gum in peach trees. As everyone knows, a wound of any kind will bring about gum flow in peach limbs, but there are several other causes which may result in the formation of gum. Streams of gum often appear at holes made by borers; the wounds in young fruit made by the curculio will also produce gum; where fungi are working in contact with living tissue, gum is usually plentifully produced: the Brown Rot fungus is particularly notable in this respect; gum pockets or "blisters" under the bark are not infrequent; similar masses of gum are occasionally formed in the tissue of the fruit; the kernel in the fruit may fail to develop and be replaced by a gum deposit; if we introduce under the bark of a healthy limb various chemical substances we can induce a copious gum flow. These examples are so different in character that we may conclude that gum in a canker should be regarded more as a natural result of some sort of injury or irritation to the tree than as a symptom peculiar to the canker itself.

General Course of Development.—What, then, is the real nature of cankers? We find it by tracing them back to the earliest stages, which has been done very thoroughly in the course of our work. It is found that in the earliest stage the canker starts from some dead wood or bark. This dead tissue may arise in a number of ways, which will be mentioned later. The dead bark is then invaded by a canker fungus which, after establishing itself in the dead portion, attacks the surrounding living tissue. It grows slowly through the living tissue, producing an open sore which increases in size year by year.

It is apparent, therefore, that the course of the disease may conveniently be divided into two distinct stages. The first stage has to do with the formation of the small dead area in the limb, while the second stage is concerned with the yearly extension of this initial dead portion by the canker fungus. These two stages will be dealt with in order.

THE FIRST STAGE—POINTS OF ORIGIN FOR CANKERS.

When we come to consider the various ways in which the necessary small beginning of dead tissue arises in the limb, or in other words, where cankers originate, it is found that there are quite a number of different starting points. An orchard survey was made in order to determine this and other points in connection with the disease, and a summary of the results obtained are here given:—

Summary of Peach Canker Survey:—

Orchards covered	11
Trees examined in these	110
Total no. of cankers in all these trees	2,609
Average no. of cankers per tree	23·7
Highest no. found in one tree	66
Lowest no. found in any tree	8

Total number of cankers classified as to dangerous character:—

A. On trunk, in crotches or on main limbs where they threaten a part which would involve a permanent loss of importance	202 or 7·8%
B. Those on larger limbs which if cut off would cause appreciable loss but which might be replaced in time	1,186 or 45·4%
C. Minor cankers on smaller limbs, the loss of which would be small or quickly replaceable	1,221 or 46·8%

Classified as to point of origin:—	No.	Per cent.
On the trunks	37	1·4
In crotches of stem and main limbs	88	3·4
Cankers around the bases of dead twigs	1,357	52·0
From pruning wounds	860	33·0
From about dead buds	90	3·4
From flowers	2	.....
From fruit stems	108	4·1
From wounds (other than by pruning)	52	2·0
From frost cracks	15	....

From these results, as well as from a vast number of other observations, the following information has been collected concerning this inportant phase of the subject:—

(*1*) *Cankers arising from dead twigs.*—In passing through a badly cankered orchard one can hardly help observing that almost every other canker has an old dead twig projecting from the center of it. This would seem to indicate that many cankers arise from such twigs, and such a conclusion is amply confirmed by studying the condition of a number of the earlier stages that may be found almost anywhere. It is obvious from such a study that a very large number of cankers start about the bases of dead twigs. In the survey tables where all the cankers found on the trees were taken count of, it is seen that out of 2,609 cankers, 1,357, or 52 per cent, have started in this way. Typical cases of cankers arising from dead twigs are shown in pl. 2, figs. 7, 10, and pl. 6, fig. 27.

The question of the part played by dead twigs in forming cankers is therefore well worth looking into.

Dead twigs are common enough in peach orchards. Some of these twigs are killed by winter. The peach is quite at its northern limit in the Niagara district, and a certain number of the less vigorous shoots perish each winter. This is especially likely to happen in the case of those shoots on the larger limbs in the centre of the tree which are too shaded to grow and mature well. There is also a certain tendency on the part of the tree to cast off some of the useless or shaded shoots, and winter conditions perhaps only serve to assist this natural pruning in many cases. In other instances, Leaf Curl is so severe on some of the shoots in spring that they do not recover from its attack. Many other twigs are killed by what has been called the " die-back " fungus (*Valsa leucostoma* (Pers.) Fr.), which will be described later. In this case the fungus is

usually able to attack and destroy only those shoots which have been first weakened or injured by some other cause; it is apparently unable to do serious damage to healthy, vigorous shoots.

Another factor in the death of peach twigs is the Brown Rot fungus, to which is due the well-known rot of plums, peaches, and cherries. When a peach rots on the tree it very often does not fall off, but remains hanging to the twig. After a few weeks, such a rotted fruit shrivels and dries up into what has been very aptly termed a "mummy" (pl. 3, fig. 12). The fungus which caused it to rot remains alive inside it, however, and will start to grow during the next spring, thus starting the rot disease anew for the next season. Because of this habit of carrying the disease over winter, it is the custom of careful growers to remove all these mummies from the trees at pruning time. While this practice is of great use in checking the Brown Rot, it quite overlooks another important source of damage in connection with this disease, a damage which has a very close relation to peach canker. This is the killing back of twigs or shoots on which the rotten fruits are borne.

Fig. 1.

To the left is shown a mummied peach which has killed its twig back to the branch. The leaves are wilted and gum is produced, particularly on the limb around the base of the twig. On the right the same twig a year afterwards; the fungus *Valsa* has attacked the twig and will later invade the thickened callus about the dead area killed the preceding year, thus forming an extending canker.

When a rotten peach remains attached to the tree, it very often happens that the twig which bears it wilts and dies. The leaves droop and fall off if the injury is slow, or they die quickly, turn brown, and stay on the shoot if the injury is rapid. The twig itself shrivels up and dies for some distance back from the rotten fruit, often to a length of two feet or more. If one cuts such a twig it is found that the wood is brown or blackened; and if the bark is peeled it is found to be entirely dead. The inner bark often covers a layer of slimy gum. In many cases so much of this gum is formed that it bursts out in blobs through the bark (text fig. 1). The browning of the wood of the twig may be noted a long distance back from the rotted fruit. In some of the shoots, discoloration has been observed from two to three feet back from the mummy.

The conditions that were observed in the shoots killed back in this way from rotten fruits at once raised the question: How far does the Brown Rot fungus itself penetrate into such twigs? In order to secure information on this point, a considerable number of test tube cultures were made from the inner bark of these twigs, at intervals along the dead and dying portion. As a result

of these cultures it was very evident that the fungus itself was not present in the twigs, or was only very rarely present, and that the killing of the twigs must be due to something passing back into the twigs from the rotting fruit. That this is actually what happens was clearly demonstrated by pressing out the juice from a number of rotting peaches and tying bottles containing this juice on the cut ends of small shoots so that the severed ends dipped into the liquid. In every case the twigs died back in the same way and to the same extent as did those where the rotten fruits hanging on the tree were responsible.

Additional work along the same line showed that acids of the same degree of acidity as the rotted-peach juice killed the twigs very readily; that as the rotting process went on in peaches their juice became from two to three times as acid as at first; and that when the juice of rotted peaches was dried the powdered residue was very injurious when inoculated into peach limbs.

The conclusion that may fairly be drawn from all this work is that the juice of rotting peaches is very poisonous to the tree, and where rotted peaches are allowed to remain on the tree their juice, passing back into the twigs, kills these very readily and for considerable distances.

The bearing of this conclusion on the question of peach canker is obvious. Where a rotten peach is borne on a shoot but a short distance from a large limb, the killing due to the rotting fruit will extend into this limb from the shoot and will destroy a greater or smaller area around the base of the twig and thus give rise to the first stage of a canker under almost ideal conditions (text fig. 1, pl. 3, figs. 12, 13). Even where the rotten fruit is located on a twig some distance out from the main branch, the destructive action of the juice may still run back far enough to injure the branch slightly. Even the dead twig itself may serve perfectly well as a base of operation for the canker fungus.

It is apparent from the preceding paragraphs that, on account of the important part played by rotted fruits in starting the first stages of cankers, the proper course to follow in dealing with such fruits is to pick or knock them off from the trees *at picking time*, before they have had time to bring about the damage just described. When these mummies are allowed to remain over winter to be removed at pruning time, their share in starting cankers is all done, and only one benefit is secured by getting rid of them. It is certain that the earlier removal suggested, which will work on the principle of "killing two birds with one stone," must be adopted in time.

The above exposition on the relation of dead twigs to peach canker may be briefly summarized here. In the orchard survey, 52 per cent of cankers were found to be started from around the bases of dead twigs. These twigs may have been killed in a number of ways—by winter, by Leaf Curl, by natural pruning, by the die-back fungus, or by Brown Rot. In many cases various combinations of these factors are responsible. Thus a twig weakened by Leaf Curl may be finally destroyed by *Valsa*, or a shaded and sickly shoot may be killed by winter, etc. No matter what the cause of death, such twigs provide small areas of dead tissue at their bases in which the canker fungus can establish itself, and then by extending this area from year to year bring about the second stage of the canker process.

(2) *Pruning wounds as sources of cankers.* Second in the list of starting points for cankers must be placed wounds made in pruning. According to the survey tables, there were 860 cankers started in this way in the 110 trees examined, or 33 per cent of the total number found in these trees. Fig. 2, pl. 1, illustrates very well the nature of such cankers, which are frequently very damaging.

How does a canker arise from a pruning wound? The answer to this question is naturally closely bound up with another question: How can a pruning wound be made which will not start a canker?

Since the canker fungus starts in some dead part, and from this attacks adjacent living tissue, we may expect to find an answer to both questions by a study of the dead tissue which arises in and about pruning wounds.

Peach trees are usually pruned in the latter part of the winter. In the period between pruning and the beginning of growth, which may be a month or more, there are quite a number of fine, warm days in which drying out of the cut surfaces can take place. In this way the bark and living tissue around the edges of pruning wounds die back, thus leaving a perfectly suitable situation for the canker fungus to begin its work. In the photograph given (pl. 1, fig. 2) there is shown around the lower edge of the cut surface a narrow band produced by the dying out of the bark after pruning. The canker fungus establishes itself in such situations and may even extend the dead area in the warmer weather of early spring, so that by the time the protective callus can be formed the fungus is firmly seated and a canker begun.

In a great many cases the formation of cankers is rendered very much easier by carelessness in making the pruning cuts. Where the cut is made too far from the junction, a stub is left which dies of itself because all the sap flow is directed through the remaining branch. Also a square cut instead of a slanting one often results in the death of tissue for the same reason (text fig. 2). Again, in pruning off unnecessary twig growth from the larger limbs, stubs are frequently left, and these are a very common starting point for cankers (pl. 1, fig. 4).

Text Fig. 2.

Development of a peach limb for four years, showing, (1-4), that a pruning cut made too far out will result in a dead stub, and later on a canker will be formed about this stub; and, (5-8), that a close slanting cut makes a pruning wound which will soon heal over without cankering.

It is realized that pruning wounds are unavoidable, and that even with the best intentions it is not always practicable to cut off the limbs in the ideal manner (text fig. 2). Still, from a careful study of this question, it is concluded that a geat deal may be done to reduce cankers by some attention to pruning methods, both with reference to close cutting and in regard to doing this work as late before growth starts as is possible.

(3) *Cankers from other wounds.*—The close attention that a peach tree receives in spraying, pruning, cultivating, and picking, subjects it under careless handling to a number of small wounds. Implements and harness cause the most of these, but a considerable number are due to pruning tools which are allowed to slip, and thus cut, tear, or bruise the bark. Any of the wounds thus made may start a canker, and often one that is located in a vital spot in the tree. Owing perhaps to the small amount of dead tissue which is present in these wounds, a smaller number of them develop cankers than one would expect. Still the survey figures show 52 cankers of this type in 110 trees, and as they are

likely to occur on the larger limbs, wounds of this nature are of considerable importance as a source for cankers.

(4) *Brown Rot in fruits and fruit spurs.*—The action of this fungus has already been described in connection with cankers started at the bases of twigs killed back from rotten fruits. In a number of cases cankers are started on the small branches by the action of rotted fruits (pl. 3, fig. 13). Although these cankers are essentially of the same nature as those started about the bases of twigs, special reference is made to this particular type on account of the fact that there is a tendency to regard all peach cankers as "Brown Rot Cankers," typically arising from the bases of fruit spurs, and both started and extended by the fungus in question. As will be shown later, this view is quite disproved by the results of our work on peach canker. As far as we can see, the Brown Rot fungus acts as an initial agent only, and while it may readily bring about the first stage of cankers it is considered to play little if any part in the second stage—the succeeding yearly extension of these.

(5) *Cankers from flowers.*—It is no uncommon thing to see a peach twig with a small dead area around the base of the stalk of a withered flower. Often this dead flower shoot has developed a small gum mass, and in some instances the twig may die outward from this point of injury (pl. 3, fig. 11). These flowers are almost invariably killed by the Brown Rot fungus, and in occasional years so much of the bloom may be destroyed in this way that the setting of fruit is materially reduced. In 1916, when the bloom was somewhat scanty from other causes, the damage from this cause was quite noticeable.

The flower shoot and the small area killed at its base serve as the beginning of a small canker which may either heal over as the limb increases in size, or may develop into a typical canker. Cankers of this sort are not regarded as important, however. Their number is not usually very great, and nearly all of them are later pruned off so as to leave only healthy shoots.

(6) *Bud Cankers.*—Cankers sometimes arise about dead buds also. Such buds are killed by winter or by the Brown Rot fungus or by *Valsa*, and small cankers are begun in the twigs about their bases. As in the case of flower cankers, these are relatively unimportant, although 90 of these were found in the 110 trees covered by the survey.

(7) *Cankers in crotches.*—A very important starting point for cankers is in the crotches of trees, and while the number of cankers so formed is comparatively few (3·4 per cent) they are individually so dangerous that special attention should be given to this type of canker. Large portions of trees are frequently lost by cankers of this nature, occasionally by the girdling of the base of a large limb, and more frequently through mechanical weakening of the "bridge" tissue of the crotch. The reduction in mechanical strength is often accentuated by the action of rot fungi as already mentioned. It has been noted many times that the cankering process is especially virulent in the crotches of trees. This may be due partly to the accessibility of the cracks in which the cankers start to rain-carried spores of the canker fungus, partly to the abundance of moisture, partly to the thick growth of barky tissue in this region, and lastly to the action of frost.

With regard to the part played by frost in this case it may be of interest to mention that in young Baldwin apple trees there often occurs a winter injury which is confined to the tissue in and about the crotches of the trunk. This injury is commonly held to be due to severe cold weather acting on tissues which have not completely attained the dormant condition. It is possible that injury of this kind in the peach might be the forerunner of canker formation. In any case, crotch cankers are very destructive, and in future efforts to control the disease special consideration will have to be given to this type of canker.

(8) *Frost crack cankers.*—A small proportion of cankers originate from cracks due to splitting of the wood and cortex by frost. In a few instances, small twig

cankers have been met with which arose from the bursting of water-filled tissues during a late spring frost (pl. 3, fig. 15). In other instances, cankers are formed on the trunks and main limbs at frost cracks, such as occur in a number of trees; in these cases, inequality of expansion strains rather than excessive water is the most important factor. As in the case of sunscald, there may be little outward indication of these cracks until the canker process reveals the presence of a lesion. Quite a number of instances have been met with where old cankers on the trunks of trees have in their centres frost cracks from which they have obviously started (pl. 6, fig. 29), and intermediate stages from the freshly opened crack up to the old canker have often been observed.

(9) *Gum blisters as sources of canker.*—Blisters of gum are frequently to be met with, especially under the bark in the cortex of the larger limbs. They seem to be freshly formed in spring, and are perhaps due to the tearing of tissue caused by the swaying of such limbs in the frozen state in winter, when the elasticity of the tissue is low. With the flow of sap in spring, such torn tissue reacts like any ordinary wound to form gum which, however, is imprisoned under the bark in the form of a blister.

A number of these blisters have been marked and followed for a year. Most of them dried up as time went on, the gum forming a hard, brown, lens-like layer in the cortex. Several which broke, either by accident or because of too great an internal pressure, became contaminated by fungi, and, in a few of these, conditions arose which were typical of cankers. None of those observed developed into permanent cankers, however, as, owing to the growth of the tissues below, the whole blister was thrown off, and a bark layer formed under it, just as healing takes place in a superficial bark wound. There is reason to think, on the other hand, that these blisters may sometimes give rise to cankers, though the number of cankers that are begun in this way is apparently so small as to be quite negligible.

(10) *Sunscald cankers.*—Sunscald areas on peach trees are not readily discovered until some time after they have been formed, on account of the band-like nature of the bark, which preserves the normal appearance of the trunk until additional growth in the adjacent living parts leaves a distinct depression on the killed area. In a considerable number of cases, canker conditions arise in connection with these sunscald areas and the original injury is increased from year to year. The rings in the yearly widening dead area around the portion of the trunk originally killed establish clearly enough the manner in which these large and very dangerous cankers are formed (pl. 1, fig. 3).

THE YEARLY EXTENSION OF CANKERS.

Having outlined the principal points of origin for cankers, it now remains to discuss how the yearly extension takes place. It is to be noted here that in plenty of cases a dead twig, a pruning wound, or any other break in the bark may exist without giving rise to a canker, and it is for this reason that the extension of cankers must be considered as a separate question.

After much observation and experiment the conclusion is arrived at that the extension of most, if not all, of our cankers is due to the work of a fungus common in peach orchards, viz. (*Valsa leucostoma*). Whatever be the point of origin, whether winter-killed twig, Brown Rot injury, pruning wound, etc., it is this fungus which extends the original dead area and keeps the canker increasing in size from year to year. If this fungus does not infect the dead tissue the wound will heal over in a few years in the normal way.

The canker fungus (*Valsa leucostoma* (Pers.) Fr.).—In any old peach orchard one may readily find dead limbs or twigs which are dotted with numerous small pimples (pl. 4, fig. 16). If one peels the outer bark from these pimples there may be seen underneath a small dark-grey or blackish lump about the size and shape of a pin's head, or like a flattened grain of shot. These are the

spore-bearing organs of the fungus. When mature they send out from the pimple tiny, reddish threads made up of innumerable spores held together by a gluey substance. Dew or rain will wet the glue and washs the spores all away, but one may see the spore threads quite readily by putting a pimply twig in a bottle with a little water in the bottom. In a day or two the threads will appear.

Before these spore-bearing organs appear on a limb, the fungus has grown all through the bark of the limb or twig in delicate threads, which soften and destroy the soft inner bark. Then the pimples appear, followed by the spore threads, and finally the spores are washed or spattered by rain or carried in other ways all about. The more numerous they are the more readily will other dead or dying twigs, wounds, and bits of dead tissue be affected.

Cultures from cankers.—It is easy enough to get this fungus to grow in cultures either from spores or by starting it from bits of the inner bark taken from an infested twig or branch. Many such cultures have been made at various times. Its presence in cankers has also been demonstrated in the same way, and it may be said that the results of 308 cultures made from the tissue of cankers show that *Valsa* is almost constantly present in the dead and dying bark tissue about cankers.

On account of the suspicion that arose concerning the Brown Rot fungus as a cause of cankers, particular care has been taken to see if this fungus is present to any extent. Out of all the cultures made from canker tissue, the Brown Rot fungus has only been recovered in ten cases. In all these cases the barky tissue which yielded the Brown Rot fungus was from the very earliest stages of incipient cankers, where it undoubtedly was active in killing the bark, having entered from a bud, flower, or fruit. In no case, however, was this fungus recovered in cultures made from old cankers, i.e., those in which the initial dead area was being extended. Moreover, although the Brown Rot fungus is readily found in incipient cankers arising about buds, flowers, and fruits, a very much larger percentage of these cankers yielded *Valsa* when subjected to culture, thus indicating that barky tissue killed by Brown Rot is early infested by *Valsa*, which apparently soon displaces it.

Several other fungi occur in cankers, but the prevalence of *Valsa* above all others indicates that it is the chief agent in forming cankers.

Artificial production of cankers.—In order to test the ability of *Valsa* and other fungi to produce cankers, a number of inoculations were made on healthy peach limbs at various times of the year. In addition to those with *Valsa*, inoculations were made with the Brown Rot fungus and several others which had been found in cankers, or which were suspected of being able to induce cankers. In making these inoculations a bit of the fungus from a culture was introduced under a V-shaped flap of bark, and the wound was then wound with strips of cloth dipped in grafting wax. Usually two such openings were made, one for the inoculation and the other to serve as a check (pl. 4, figs. 19, 20). The results of the 408 inoculations made in this way were very striking. Of all the different fungi tried only two, *Valsa* and the Brown Rot, had any marked effect. Both these, when introduced into a small V-shaped slit in the bark of a peach limb, set up a pronounced disturbance, killing the surrounding tissue for from one to three inches, and causing copious gum flow (pl. 5, figs. 21, 22).

It is to be noted here, however, that in the case of the Brown Rot fungus the effect ended with that season: In none of these inoculations was the wound extended during the next season, but they all healed up in a normal fashion. Professor Caesar also found that in inoculations with the Brown Rot fungus the wounds healed without extending, and in 1913 the Dominion Botanist, Mr. Gussow, notes that he obtained the same result from similar inoculations.

In the case of the *Valsa* inoculations the result was quite different. In the next season the fungus made an advance into the surrounding tissue, and thus

produced a true canker comparable with those found naturally in the orchard. Photographs of these artificially produced cankers which are extending after the first year are shown in pl. 5, figs. 23, 24, 25 and pl. 4, fig. 17. In all these the pimples characteristic of *Valsa* are quite evident.

The evidence from inoculations therefore agrees with the results of cultures and with the orchard observations, in showing that *Valsa* is active in extending cankers and that the Brown Rot fungus is not.

How the fungus extends a canker.—Every canker may be considered as a battle-ground where a bitter war is being carried on between this fungus, on the one hand, and the living tissue of the tree on the other.

At one of the points of origin already mentioned where there is some bit of dead bark, as at the base of a dead twig or a pruning wound, the fungus lands its forces in the form of spores carried or washed from some infested limb. Then the struggle commences. The growing tissue of the limb defends itself by building a wall of cork-like texture between it and the invaders. This wall is the thin but very impervious bark on the surface of the callus growth, and if it is kept intact the fungus is stopped. During the growing season, even if the fungus enters this wall at a crack or break, a new wall of cork, a second line of defence, is hurriedly built behind it, and the tree is once more secure.

Unfortunately there comes a time when the living tissue loses its only power of defence. It must go into the dormant state in order to pass the winter safely, and once in this condition it is helpless, because it is only through growth activity that it can keep up its wall of defence. From fall till spring, then, the fungus marches slowly but steadily on, taking advantage of warm, mild days to grow forward. If the cork wall has no break in it the fungus will in most cases be able to turn the flank by working around underneath the inner edge of the protective layer where the callus growth has to fuse with the old heart wood. Once inside, the progress of the fungus is only checked by weather conditions until spring, when the living tissue wakens into activity and promptly builds another callus, with its protective cork layer, ahead of the advancing enemy. And so the losing fight goes on year after year. Each summer the fungus is held up for a time, and each winter it passes the defense and conquers more territory, until the limb is girdled completely. Each summer the living tissue about the canker shuts out the fungus and forms its callus layer, and each winter the fungus invades and destroys part of this callus. The result is that in a canker of several years' standing there can be made out a series of rings (pl. 2, fig. 8) representing the successive yearly efforts of the tree to stop the fungus. If the gum and dead tissue are cleared away from any old cankers, these rings will be plainly seen.

Frost injury in cankers.—Ordinary observation shows that plum and peach trees killed or injured by winter are very shortly covered by the pimples of *Valsa*. Also twigs which have been winter-killed soon become infested with this fungus, and sun-scald areas are readily and constantly attacked by it. It is apparent that winter-injured tissue is specially suited to the needs of *Valsa*, and that it can grow therein with the greatest readiness.

Some experiments were carried out to determine whether freezing a healthy peach limb made it more susceptible to the attacks of *Valsa*. Three areas on each limb were washed with alcohol to sterilize them. An oval spot about 1 by 1½ inches was frozen in the upper and middle areas, and the middle and lower areas were inoculated with the fungus. In this way the upper area was frozen but not inoculated, the lower was inoculated but not frozen, while the middle area was both frozen and inoculated. All were wrapped with waxed cloth, and left. The results were very uniform and outstanding (pl. 4, fig. 18). The upper area (frozen only) recovered without swelling or gum formation; the lower (inoculated only) produced a considerable amount of gum, and the fungus killed the bark for from half an inch to an inch; in the middle area (frozen and inocu-

lated) the effect of the fungus was much more pronounced. Not only was all the frozen area totally destroyed with excessive production of gum, but the fungus had extended its work beyond this area for another inch or more. It is thus apparent that if the living callus tissue about cankers was injured by winter the action of the fungus in extending the canker would be greatly increased.

In connection with crotch cankers there has already been recorded a suspicion that their virulency may be due in part to winter injury. There is also some ground for thinking that winter freezing may play some part in extending the ordinary cankers.

It is well known that the tissues of trees which have not gone into the dormant state before winter are readily killed by the first severe cold. Now, the callus tissue about cankers is highly stimulated by the cankering process, and as a result it grows in a much thicker layer than elsewhere on the limb. Owing to various causes this tissue is still active late in the season, long after the rest of the tree has become dormant. There is good ground for thinking that in many cases this callus is injured by early winter, after which an invasion by *Valsa* takes place with great ease.

It has often been noted in this connection that where a portion of the callus around a canker is exposed to the light and air it is not extended in winter, while in other portions, which are covered with gum, are moist and tender, and are kept active by stimulation, extension takes place almost constantly.

Insects in cankers.—When old cankers are cleaned out, white "grubs" are often found buried deep down under the gum and dead material (pl. 6, fig. 27). These are the larvæ of the Lesser Peach Borer, which find in canker tissue a favourable condition for existence. The gum and dead bark give them ample protection besides supplying them with moisture. They feed on the tender tissues of the callus growth around the edges of the canker, and thus assist in enlarging it from year to year. As many as nine of these larvæ have been found in a single canker, but others have none at all. On account of the presence of so many of these larvæ in cankers, there has arisen a popular belief that the larvæ cause the cankers. This is not at all the case. Many older cankers, and all cankers in the early stages, are without any of these larvæ; hence, whatever harm they may do in extending the cankers, they can have little or nothing to do with causing them.

SUMMARY OF CANKER DEVELOPMENT.

The preceding detailed account of canker formation may here be shortly summarized:—

(1) A canker starts in a dead portion of the tree.

(2) This dead portion may be a dead twig, a pruning wound, a dead bud or flower, a split crotch, sunscald area, or any other spot where dead tissue is present.

(3) The canker fungus (*Valsa leucostoma* (Pers.) Fr.) establishes itself in the dead portion and attacks the surrounding living tissue.

(4) The fungus causes a heavy flow of gum and stimulates the surrounding tissue into excessive growth, so that a pronounced callus ring is formed around the canker.

(5) The fungus advances into the surrounding living tissue when the tree is dormant. Its attack may be assisted by the freezing of the stimulated and unripened callus around the canker.

(6) Successive advances are thus made each winter until the limb is girdled.

CONTROL OF CANKER.

The subject of control naturally divides itself into two parts—prevention and cure—and of these two, prevention is the more important.

Prevention of cankers.—With a clear understanding of the nature of the disease, supported by the knowledge of orchard conditions supplied by the survey figures, it is possible to say with some confidence what measures should be taken to avoid cankers in trees. Two features are plainly concerned: (1) the elimination of the fungus *Valsa* from the orchard, and (2) reduction in the number of dead parts from which cankers may be started by this fungus.

Ridding the orchard of the fungus is mainly a question of cleanliness in pruning. The spring spray, as ordinarily applied, will take care of the spores which adhere to the bark and limbs, but since the fungus lives under the bark where spray cannot reach it, and since it produces spores all through the year, spraying alone is utterly unable to deal with the canker fungus. The only way by which it can be destroyed is by cutting out every bit of dead and weakly wood which, either bears the fungus or which might become infected with it. There is every hope that this method will give good results. It has been noted already that the spores are mostly spread by water, that is, by the splashing or washing action of rain, so that infection of clean orchards by those at a distance will not be readily brought about. This is an important point, because not only does it assure that attention given to an old orchard will not be wasted, but it indicates that a young orchard will have every chance of growing up free from the disease if the pruning of dead wood is thoroughly done in the early years.

Concerning the second feature in prevention—the reduction of the number of starting points for cankers—little can be added to what has already been said in the section describing the various points of origin for the disease. It is there shown that the fungus attacks the living wood only from some adjacent dead tissue, and this dead tissue may be a dead twig, a dead bud, or flower shoot, or the dead tissue around wounds. Since the survey indicates that 85 per cent of all cankers may be attributed to dead twigs and pruning wounds, the chief attention from this point of view must be centred on these very important factors. In the case of twigs killed by winter or Leaf Curl, pruning is the only way to deal with them, but the cankers which start through twigs killed by rotted fruits are clearly preventable by removing the rotten fruits before the damage is done.

With regard to the numerous shoots which arise from the main branches, especially in the case of trees which have been severely pruned, a suggestion is here offered. Many of these shoots die in winter and are then attacked by the canker fungus, and damaging cankers are started at their bases. Even if these dead shoots are pruned off in early spring the dead stub which must be left is a frequent starting point for the canker disease. On the other hand, if one goes over such trees about July 1, when these shoots are well started but are still soft and brittle, they can be all rubbed off with the gloved hand very quickly and without the slightest trouble. The separation takes place right at the bark of the limb, and the small wound left heals completely before the summer is over. In this way all danger from cankers started by these water shoots can be totally avoided. This practice is especially recommended for young orchards, since the cankers started by water shoots on the main limbs will become dangerous just when the orchard comes into profitable bearing condition.

In the discussion of pruning wound cankers there is indicated the only means that seems to be practicable in the pruning process as an aid in preventing cankers—cutting limbs off close so that no dead tissue will result (text fig. 2). It is probable that a great deal of pruning wound infection is due to the operation itself. The tool is used to cut off a healthy limb after having removed a dead

one which bears countless spores of *Valsa*, and there are doubtless carried to the second cut a considerable number of these spores. The use of an antiseptic on the pruning instrument would prevent danger from this source, but it is realized that under present orchard conditions treatment of this nature is almost out of the question. On the other hand, if the spray material could be applied in the fall or early winter, as has been sometimes thought feasible, the presence of a recently applied coat of spray on the limbs would no doubt help in a great measure to sterilize the pruning cuts.

The only way in which crotch cankers can be prevented is by heading the young orchard so that the formation of crotches and V-shaped forks will be avoided. It is not always easy to do this, but in view of the extremely virulent nature of the cankers which arise in crotches, and the losses which they cause, any efforts towards eliminating them will be repaid.

The various other types of cankers mentioned (bud cankers, flower cankers, frost cankers, and those from other wounds) are so few in number or so insignificant in their consequences that no account need be taken of them in preventive measures.

The measures just advocated to prevent peach canker may be shortly summarized as follows:—

(1) Keep the trees free from all dead and dying wood which might harbour the fungus.

(2) Prune out all dead twigs, especially on main limbs, so that they cannot serve as starting points for cankers.

(3) Rub off all unnecessary sucker growth in summer when it is soft, instead of leaving it to be pruned out after it is mature.

(4) Get rid of the rotten fruits on the trees at picking time; if left hanging to the tree they are likely to start cankers.

(5) Make all pruning wounds clean cut, and cut as close to the remaining limb as possible. The later in the spring pruning can be done the better the wounds will heal.

(6) In starting a young orchard the heads should be started so as to avoid crotches and V-shaped forks. These are likely to split and very dangerous cankers may be formed in the fractures.

CURE OF CANKERS.

Since peach cankers are extended by the action of a definite fungus which attacks vigourous living wood so slowly that material progress is possible only when the host tissues are dormant; which attacks living tissue after becoming established in adjacent dead parts; and which cannot penetrate the unbroken periderm but depends for entrance on breaks or weaknesses in the protective layer: then it is apparently quite possible to arrest the process of extension by suppressing the factors favourable to the fungus.

If the dead wood, bark, and gum are carefully removed during the early part of the growing season so that a normal callus, well ripened for winter, can be formed about the canker; if the wound be kept dry and open to air and sun during the summer, a perfect healing of the canker will ensue, though the wound itself may not entirely close over for a number of years. Owing to this slowness in healing, the exposed heart-wood in the wound is liable to the attacks of rot fungi, so that some antiseptic wash, followed, when the wood is dry, with a protective coat of some kind is advisable (pl. 6, figs. 26, 27, 28).

Over 300 cankers have been cleaned out and treated in various ways in order to ascertain the best method, and many hundreds more have been treated in this district by several interested fruit growers of their own accord. The results show: first, that to be successful, the cleaning of the canker must be fairly careful, otherwise extension will take place from the neighbourhood of some neglected part; second, that healing proceeds just as well where no

antiseptic or protective coat is used as when these are applied, provided the wound is kept clean and dry; third, that where paint or some similar protective covering is not applied to the exposed wood, rot and consequent weakening follow in two or three years; fourth, that ordinary lead paint is the best protective material for this use. Fig. 30, pl. 6, shows a canker which was so bad that only a band of living tissue half an inch wide was left along one side. It was cleaned out, washed with corrosive sublimate (1-1000) and then painted with lead paint. After two years, at the time the picture was taken, no signs of cankering were visible, the strip of living wood had increased in size rapidly, the exposed heart-wood was still quite sound, and the limb was as healthy as its neighbours.

It is admitted that the cost of treating cankers in this way in a large orchard would be very great, and to apply such treatment to all the cankers on a tree is out of the question. Since the time and materials employed have been estimated from actual work at about 5 cents per canker, it is well worth while to use this method for those old cankers which menace a considerable portion of the tree, such as crotch cankers, or those occurring on the larger limbs.

As previously intimated, this work should be done in summer, late enough to assure the presence of a strong callus about the wound, but early enough to permit this exposed callus to ripen thoroughly before winter sets in, as well as to allow the healing of small accidental wounds made in doing the work.

It has been found that special attention has to be given to the layer of cast-off barky tissue just overlying the new growth of callus tissue, because, as previously mentioned, this dead remnant harbours the fungus, which can then from this base attack the living tissue beneath, as occasion offers.

In a few cases attempts have been made to treat cankers by cutting a slice from the limb which will take out the whole canker and leave a clean surface; an ordinary draw knife has been usually employed for this purpose. This method has the great advantage of quickness. On the other hand it usually takes too much from the living tissue at the point where it is already narrowed to a dangerous degree. In addition, such a method is much hampered by the presence of other limbs, is very difficult in the numerous cankers around pruning wounds, and impossible to use in the case of crotch cankers. Moreover, on account of the large size of the wound left, healing over will take a much longer time, and the copious gum flow resulting from the extensive cutting of the callus tissue neutralizes to a large degree the advantage of a clean-cut surface.

The following points are worth attention by anyone who undertakes to clean out cankers:—

The tool which has been found most effective for this work is an ordinary heavy jack knife.

The best time to carry out the process is just after a heavy rain, when the gum is softened and is easily removed. The callus growth should be injured as little as possible. If the callus is cut and torn, fresh gum masses will be formed over the canker in a few days. The dead wood and gum should be scraped carefully from around the inner edge of the callus. It is at this point that extension usually commences and a little care in this operation is well repaid. There is often a thick barky layer above the callus growth, Since this is known to harbour the fungus it should be pared off until the green inner bark is exposed for at least an inch back from the edge of the canker. The ends of cankers are often wedge- or V-shaped and if these narrow ends are not carefully attended to extension will take place even after treatment. After treatment, gum will form from the wounds made. These lumps of gum should be rubbed off about three weeks after the cleaning has been done.

SUMMARY OF CANKER TREATMENT.

1. Large or serious cankers on trunks and main limbs will heal up if carefully cleaned out.
2. This should be done in summer, preferably after a rain.
3. After treatment, brush out with corrosive sublimate (1-1000) and, when dry, paint the exposed heart-wood with lead paint.
4. Go over in three weeks' time and rub off any gum exudations that may have forned from wounds.

In conclusion, the writer wishes to make grateful acknowledgement to those who have rendered assitance in this work; to the Dominion Botanist for help and suggestions; to Mr. L. Caesar for much valuable information; to the Director of the Vineland Horticultural Experiment Station for the use of trees for experimental work; to Mr. G. O. Madden for assistance in the experimental details; and especially to the fruit growers of the Niagara district who have in every case contributed cheerfully and generously the materials necessary for the study of this disease.

Plate 1.

1. A typical peach canker.
2. A pruning wound canker cleaned out to show features.
3. Sunscald canker on the trunk of a peach tree.
4. Canker developing around the base of a carelessly pruned shoot.
5. Cross-section of a peach canker showing the yearly extensions that have occurred.
6. The breaking down of a peach limb at a canker. About one-fifth of the tree is lost in this case.

PLATE No. 1.

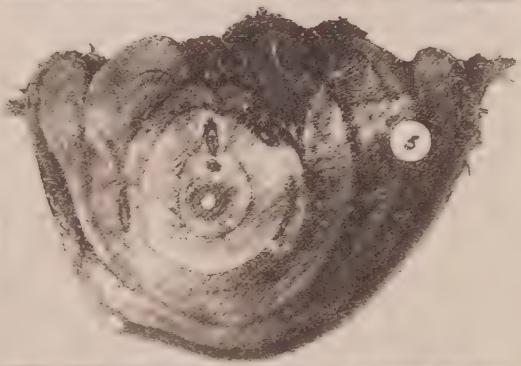

Plate 2.

7. A typical canker arising from the base of a dead twig.

8. The same canker cleaned out to show the yearly extension that has taken place.

9. Two early stages of twig cankers, showing the gum masses that are formed about the lesion.

10. The same cleaned out to show the extent of the dead tissue produced at the base of the twigs from which these cankers started.

PLATE No. 2.

Plate 3.

11. Peach shoot killed by Brown Rot. The fungus has worked back from the blossom and girdled the twig. Small cankers are often started at the bases of flowers killed in this way.

12. Twig injury resulting from a mummied fruit. Cankers are frequently started from injuries of this kind.

13. A canker of several years' standing, which started originally from a rotten fruit.

14. A canker which has been cleaned out to show the yearly extension rings. The stimulated callus growth is well illustrated.

15. Several incipient cankers started from frost cracks in spring. The large masses of gum that were produced around these lesions have all been removed.

PLATE No. 3.

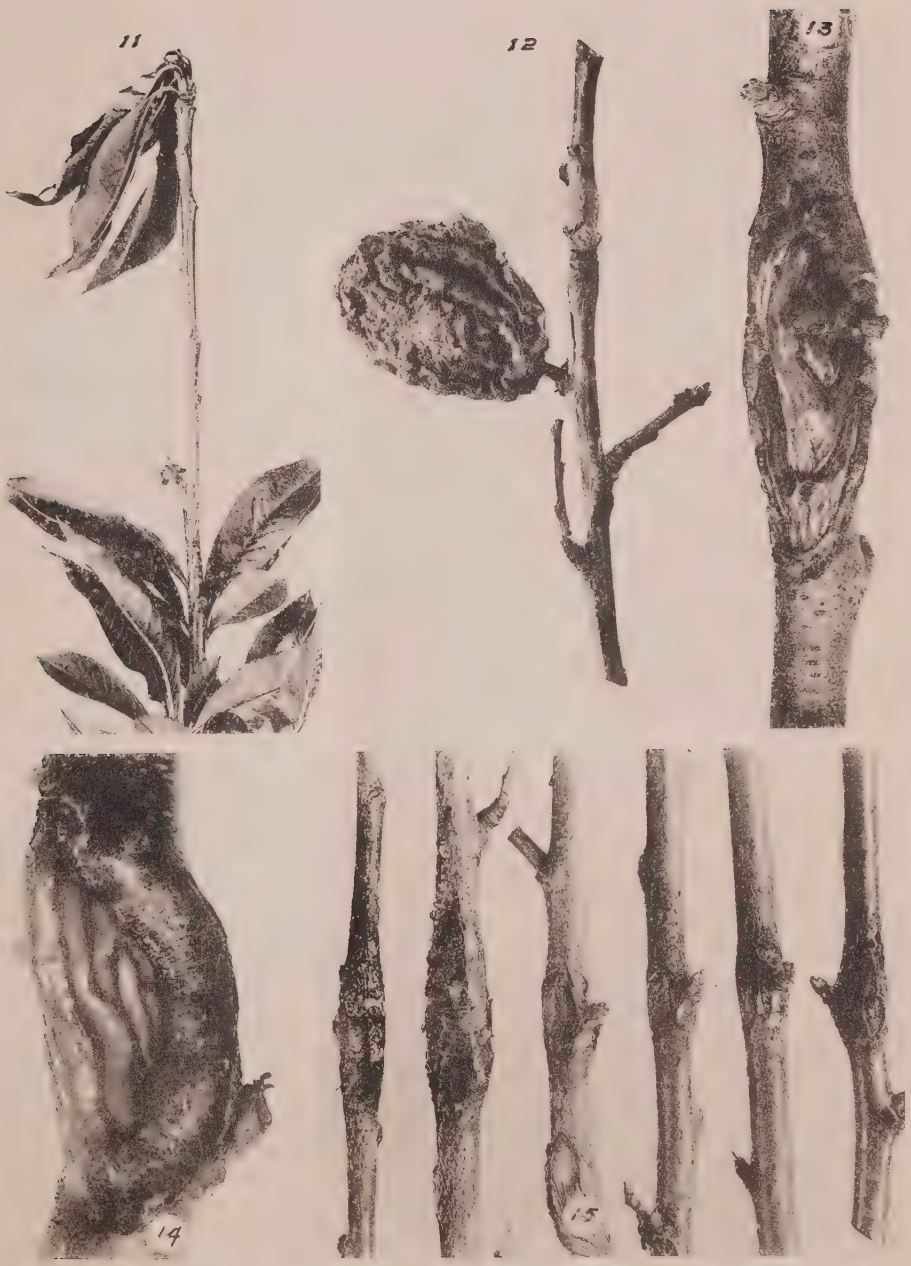

Plate 4.

16. A peach limb studded with the pimples of the canker fungus *Valsa*.

17. An artificial canker of two years' standing. The point of inoculation, and the small area invaded in the first year, are shown in the center at the left side. The small holes in the bark are left after the pimples of the canker fungus have been eaten out by insects.

18. Result of freezing and inoculation experiment. The upper (frozen but not inoculated) is little affected; the lower (inoculated but not frozen) was somewhat injured and produced large gum masses; in the center (both frozen and inoculated) a large canker-like wound has resulted.

19–20. Illustrating method of inoculation with fungi. The fungus is introduced into one slit and the other is left as a check. Both are then wrapped with cheesecloth dipped in soft grafting wax.

PLATE No. 4.

Plate 5.

21. Artificial canker produced by inoculation with *Valsa*. The inverted V marks the position and size of the inoculation slit. The copious gum masses and dead bark have been removed.

22. A similar canker produced by inoculation with the Brown Rot fungus. The gum which was produced in large quantities has all been washed out. The inoculation slit in the bark is still visible at the end of a remnant of bark.

23. An artificial canker during the second year, showing how the fungus *Valsa* has extended the small lesion produced the first season.

24–25. Three artificial cankers produced by inoculation with *Valsa*. These are taken at the end of the second year, and show how the small dead area caused in the first year is enlarged during the next season to form a true canker similar to those naturally found in the orchard.

PLATE No. 5.

Plate 6.

26. An ordinary canker as it appears in the orchard.

27. The same canker cleaned out to show: (1) its origin from a dead twig, (2) the yearly extensions that have taken place, and (3) a larva of the Lesser Peach Borer which feeds on the soft callus tissue under the gum and bark.

28. The same canker washed with corrosive sublimate (1–1000) and painted with lead paint to protect the exposed heart-wood.

29. A trunk canker which started from a frost crack, cleaned out and painted.

30. A serious canker on a limb two years after treatment. The band of live tissue on the top has grown considerably and keeps the limb quite healthy, while the paint has prevented the heart-wood from being weakened by rot.

PLATE No. 6.